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THE BREATHING PORES OF LEAVES.

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If the outer layer or skin be stripped from the surface of the green colored parts of plants and examined under a low power of the microscope, the stomata, or breathing pores, will appear as green specks in the otherwise colorless membrane. Their object is to open and close communication between the intercellular space always existing between the individual cells, and the outer atmosphere.

The sausage-shaped cells constituting the essential part of the organ are called the pore cells. They have the power of separating from each other in the middle, thus opening a free way for the air to the interior tissues; or in certain conditions of light and moisture they approach each other so as to narrow or entirely close the slit between them. They are filled with protoplasm, chorophyl and starch granules, while all other cells of the outer surface are filled only with air and water.

Apparently with the object of placing these pore cells as free as possible from all constraint or pressure, so that they may correspond sensitively to all the changes in the atmosphere, they are at times situated on a level with the epidermis cells, sometimes raised above, at others sunk beneath this level. If the epidermis cell walls are thin and flexible the stomata will generally be found in the same surface with them: but when the epidermis walls are thick and stiff the stomata will generally be found sunk deep un-

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der the surface, or raised above it, or surrounded by a ring of smaller cells with thinner walls than the remaining epidermis cells.

Immediately under the stomata are empty spaces, of irregular form and varying size, called breathing rooms. They are in connection with, and form a part of the intercellular space which ramifies through the entire structure of most tissues.

It is an interesting question, in what way the stomata have been formed. Were the pore cells at first a pair of ordinary cells, which have gradually changed their form and contents until endowed with all the peculiar properties of their natural state? Or were they always existent in their peculiarities, only smaller as the leaf was younger? Or, have they grown out of a single cell by the process of subdivision and after growth? Do they belong to the epidermis, or to the chlorophyl bearing tissues beneath? Two examples, studied in their structure and history, will throw some light on these questions.

Gasteria verrucosa, of the aloe family shows, scattered over the surface, small, thick-walled squares with a deep cavity in the centre (Pl. 3, fig. 6). These squares fall at the junction of four cells which are distinguished from the others by the absence of the little cone in the middle. In the centre of each square, at the bottom of its cavity, can be seen a narrow slit. Various sections will show more of the structure. Pl. 3, figs 7 and 8 represent thin horizontal slices seen from below; *i. e.* inverted on the stage of the microscope. The razor in fig. 8 has passed through the pore cells, and in fig. 7 just beneath them. In fig. 7 you see, shimmering through the green pore cells, the thick-walled square which was so plain in the surface view. The vertical sections, figs. 9 and 10, show the thick outer wall of the epidermis and the little cones or protuberances seen in the middle of the cells in fig. 6. In fig. 9 it will be perceived that the opening between the pore cells is not a plain straight-walled cavity, but that the two cells project in the middle, and again by means of horns or protuberances, come nearly in contact above and below, thus making as it were, a couple of little ante-chambers before reaching the great breathing room. The striped portion under the pore cell in fig. 10 represents a thickening of the cork layer which has formed there; it lies on a little lower plane than the rest of the drawing. The square cavities above the pore cells may be called the front yards of the stomata. When you drop a little of Schultz' Iodine so-

lution on a section like fig. 9 the thick outer wall of the epidermis, especially in the outer half, turns deep brown, a color which follows down the sides of the cavity, extends as a very thin layer through the slit, and fades out on the walls of the rectangle below; the substance thus colored is cork, or of the nature of cork. The main portion of the walls of the pore cells, and all the cellular tissue underneath, become violet or purple; the reaction of cellulose. The little grains in the cavities of the pore cells are of a bright blue, betokening starch; and the granular mass of protoplasm in which these are embedded becomes yellowish brown.

In studying the development of this complex organ, we take the youngest leaf of the plant, and find on its base (the youngest portion) no trace or hint of stomata. A very little higher up we find the epidermis appearing as in fig. 1, many of the cells having built a partition across their front end cutting off about a quarter of the original cells. These small cells are distinguished from the remaining portion of the originally single cells, and from the undivided cells, by being filled full of granular protoplasm while the other cells are only partially filled with the protoplasm constituting the nucleus. These little cells, called mother cells, soon grow so as to become longer than broad, and are raised by the more rapid growth of the surrounding cells so as to leave an air space below (figs. 2 and 4). An approach to a spherical form is now made by the mother cells, and the walls of the neighboring cells are a little thickened with the deposition of cork substance giving the first trace of the thick-walled square of the ripe stomata. Next the mother cell divides by the formation of a thin partition which runs in the direction of the point of the leaf, and is perpendicular to its surface. Soon this partition thickens in the middle (fig. 3) and splits through the thickened portions to within about a fifth of each end. All further growth only effects minor changes in the form of the cells, or an increased thickening of their wall. Figs. 4, 5, and 9 show the various stages of growth in cross section, and fig. 10 in longitudinal section.

In *Tradescantia discolor* the stomata, quite different in appearance, are more readily seen from the surface. (Fig. 14.) The peculiarity of these stomata consists mainly in the structure and form of the epidermis cells immediately around them and constituting a part of the stomata apparatus. The form and arrangement of these cells are shown in figs. 16, 17, and 18. The

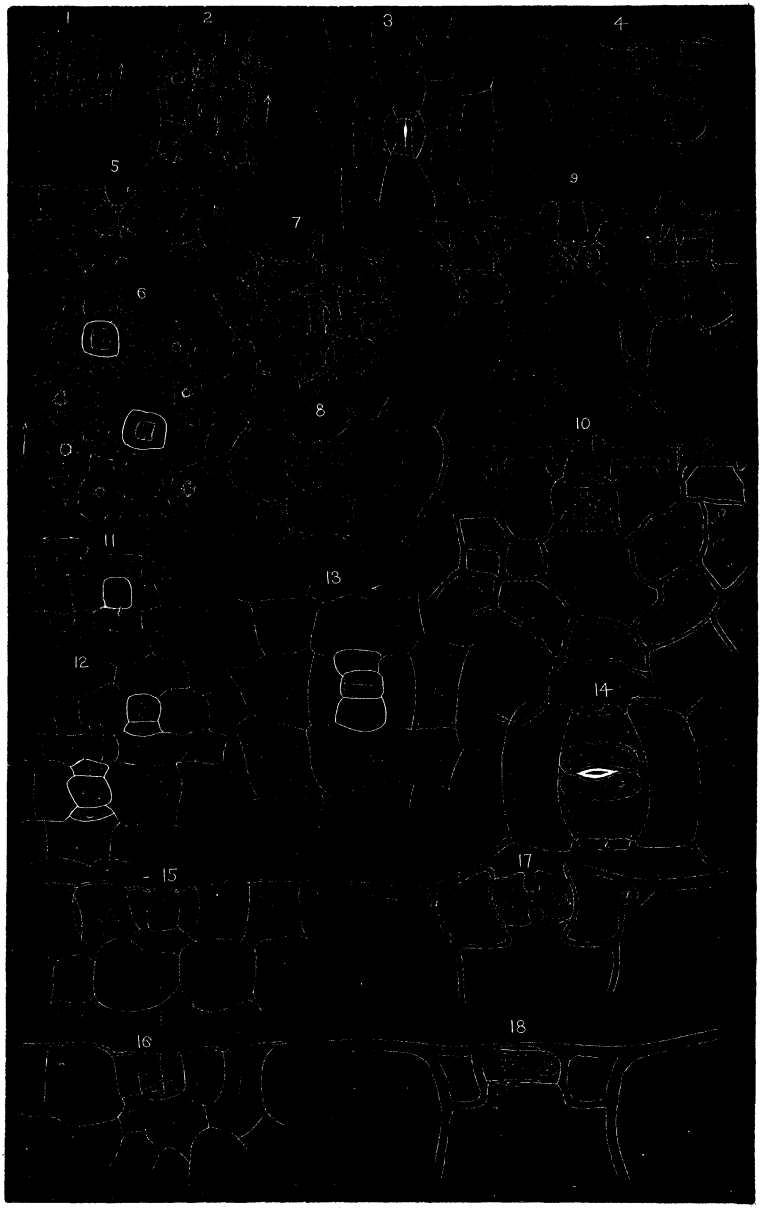
double lines in fig. 14 between the "help pore cells," as these four surrounding cells are called, are formed by projections of one cell over another, as shown at *a* of fig. 17, which when seen from above would show two contours to the same cell nearly in the same plan.

The development of these stomata is easily traced in the figures. The mother cell, shown in fig. 11, grows less rapidly than the surrounding epidermis cells, whose walls therefore stretch out as radii from its four corners. Thin partition walls are thrown across between these radii cutting off from these side cells new cells as shown in fig. 12; at *a* one of these side cells having been formed, and two at *b*. Almost immediately afterwards a pair of end cells are formed in a similar manner; and after this formation of the four help pore cells, the two pore cells are formed as described in the *Gasteria verrucosa*. Figs. 15, 16, and 17 show in cross sections the development of these organs, and fig. 18 shows the mature state in longitudinal section. The air spaces do not exist at first, but the unequal growth of the surrounding tissues causes tension which splits apart the walls dividing the cells, and thus forms and enlarges the air spaces; and in the same manner are formed the openings between the pore cells themselves.

The two examples described may serve as types of two classes of stomata, in one of which the pore cells are surrounded by ordinary epidermis cells, and in the other by modified cells or help pore cells. Within these two classes are to be found stomata differing from each other as variously as the leaves in the two great classes net veined and parallel veined.

EXPLANATION OF PLATE 3.

Figs. 1, 2, 3. Surface views of epidermis of *Gasteria verrucosa*, from first appearance of the mother cells of the stomata to the production of dividing wall between the two pore-cells.
Fig. 4. Cross section of same stage as No. 2.
Fig. 5. Cross section, somewhat older.
Fig. 6. Surface view of full-grown leaf, showing two stomata.
Fig. 7. Stomata fully grown seen from beneath, the plane of the drawing being completely under the stomata.
Fig. 8. Horizontal section of the same.
Fig. 9. Cross section of the same.
Fig. 10. Longitudinal section of the same.



BISCOE ON THE BREATHING PORES OF LEAVES.

Figs. 11-14. Surface views of epidermis of *Tradescantia discolor*, from first appearance of stomata to maturity of the same.
Fig. 15. Cross section of about the age of No. 12, *b*.
Fig. 16. Cross section of the age of No. 13.
Fig. 17. Cross section of full-grown.
Fig. 18. Longitudinal section of the same.
× 400. The arrows indicate the direction of the point of the leaf.

AQUEOUS PHENOMENA OF THE PRAIRIES.

BY PROF. H. W. PARKER.

THE igneous scenes of the prairies have become very common place in description. But where is there any account, either scientific or popular, of the interesting aqueous phenomena, in winter and in summer?

How it may be in the region protected on the north by the Lake Superior highlands and affected by the air of the lakes, the writer does not know, except that the temperature is much modified. But in central Iowa intense cold is of frequent occurrence, and there are conditions along with it that often bring out the splendors and wonders which we associate with arctic scenes. Parhelia, or mock suns, at morning or evening, are common; without exaggeration it may be said that they equal the real sun in brilliancy, and are indeed blinding to the sight. After witnessing them, an eastern man regards all that he has seen of this phenomenon at the east as insignificant. So likewise, mock moons, and both lunar and solar halos, crosses, and far-extending complicated circles of light, with bright spots at the intersections, may be mentioned as sights by no means unusual, and often of great magnificence and duration, continuing a good part of the day or night. The writer remembers, for example, a circle passing through the sun and reaching horizontally quite around the sky, making part of a cross inscribed within another circle around the sun, there being also four tangent circles at the ends of the cross; and this was visible for several hours before and after midday. The cloudless sky of the West conspires with spicules of frozen vapor, to render these effects not rare; for the West, at least beyond the vicinity of the lakes, is bright and sunny at all seasons.

Feathery crystals, frequently of great size and beauty, and completely clothing every exposed object, are sometimes to be seen